# FUNDAMENTAL CONSIDERATIONS IN THE REORGANIZATION OF HIGH-SCHOOL SCIENCE

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There has never been a time in the history of secondary education when consideration of the fundamental principles underlying high-school science courses was as necessary as at the present hour; nor has there ever been a time when those principles were receiving the attention they are now receiving. The Spencerian conception of science as a foundation for all general education has not been realized. The popular interest in science which characterized the epoch of Darwin, Huxley, and Agassiz, of Faraday, Lyell, and Tyndall has largely waned in recent years. The last decade of the nineteenth century and the first decade of the twentieth century showed a marked decrease in the *percentage* of high-school students enrolled in the science classes of the secondary schools of the United States. Meanwhile, applied science advanced by leaps and bounds. Its controlling influence in the daily life activities of all classes increased at a tremendous pace. Within a life's span it has completely revolutionized all systems of transportation and communication; it has all but annihilated time and space; it has molded all civilized peoples into a single, interdependent community; it has transformed the primitive home into the modern home with its multitude of labor-saving and life-conserving conveniences; it has, in a large measure, severed the fetters of hard manual labor from the farmer, the mechanic, and even from the common laborer; it has enabled man to subdue and harness the vast, wild forces of nature to an extent undreamed of by the Jules Vernes of a half-century ago; it has multiplied the productive resources of human effort many fold; in short, it has doubled and redoubled the available comforts and pleasures of life and, at the same time, it has cut in half the necessary hours of human toil.

In such an age, when applied science rules the activities of men, when all human activity is so dominated and determined by applied science, why should not popular interest in science be ever-increasing? Why this decline in the percentage of high-school students who are pursuing the science courses offered in our high schools? Why the present unrest and agitation by science teachers and students of education concerning science instruction in our high schools? Why the persistent demand, from every quarter that high-school science be reorganized?

If science is ever to become the basic foundation of a general education for the common people, as was held two or three generations ago to be inevitable, not only by Herbert Spencer, but also by many of the leading educators of that day, science in our high schools must be reorganized. It must be reorganized with a conscious recognition of the fact that we are now living in the twentieth century, that we have passed the period when initial interest in science rests with a mere appreciation of the great, general abstract truths of science, if, indeed, young people of high-school age ever were interested in that phase of science. It is absolutely clear that at the present time our classroom instruction must reveal to the high-school student something of the story of the discovery of the great truths of science, but especially it must make clear to him the monumental effects of applied science upon modern life.

The science courses offered some thirty to forty years ago, when the public high school was in its infancy, were interesting and popular. But the courses then offered were largely of the nature of popular science; they were spiced through and through with details and illustrations of interest to the common people. Some of us are inclined to smile at those early courses today because they were so brief, because they dealt so largely with the spectacular side of science, and possibly even because they were evidently so framed up as to make a strong appeal to the interest of the young people. On the other hand, students of education are coming to recognize that the greatest value of those early courses lay in the appeal they made to the interest of the student.

Gradually elementary courses in science became more and more barren of detail and almost devoid of those touches of human

interest which made the earlier, popular presentation fascinating. Gradually, but surely, high-school science became a condensed epitome of the college course; the dry bones of the college course were presented but the flesh and blood were gone, and with the flesh and blood went also the interest of the student.

The present organization of science materials into the special sciences for purposes of instruction, in the early years of the high school, at least, is fundamentally unpedagogical and is largely responsible for the decline of interest in science in our secondary schools. The usual course in any special science either presumes that the student is interested in the abstract, fundamental truths of science or else it neglects the element of interest as a factor in the educational process. In either case it is unpedagogical and a fatal mistake, for initial interest in science rests chiefly, if not solely, in those phases of applied science which have to do with the control of our environment, and without interest little educational progress is possible.

The units of applied science are fundamentally different from the units of pure science. The units of applied science are the natural, Creator-made, units; the units of pure science are artificial, man-made, units. Because the mature scientist appreciates and sees a certain significance in the organization of science materials into man-made units, it does not follow that the boy or girl just beginning the study of science is likewise interested in such a so-called "logical" study of abstract, fundamental principles. The adolescent is distinctively an embodiment of alert, intense impulses. But with all his keenness and alertness his interest is secured and maintained only when the subject under consideration has significance, when it has direct bearing upon his welfare or the welfare of those about him. Critical analysis, long continued, followed by synthesis, and finally terminated, possibly, by a brief mention of application, *which is the method of a special science*, may satisfy the mature scientist, but such a procedure kills all interest in the beginning high-school student. The beginner in the study of science is interested only when the order of procedure is reversed. He wants, first of all, to see the *go* of things; he must first of all be shown the

worth-whileness of the task set before him. This can be accomplished only by showing him the significance of science in its applied setting. Out of a study of applied science the essential laws and principles may be developed.

As a concrete example of the foregoing let us consider the procedure of special science organization of plant life—botany. Where is the wide-awake, fourteen-year-old farmer boy who is interested in a two- or three-weeks analytical study of roots, followed by a similar study of stems, then of leaves, and finally fruits, even though some mention of application may be made in the closing chapter? Such a boy, however, with red blood in his veins, is intensely interested in the study of corn, or of wheat, or of potatoes, the conditions under which they germinate or sprout, and under which they grow and mature. He is interested in the climatic conditions and the soil conditions best suited to their growth and maturity, and in the insect pests to which they are subject. When science teachers come to recognize that the source of interest for the high-school boy lies in the applied phases of science and not in the abstract phases, or "pure science" phases, they will cease to wonder at the fact that agriculture is popular and on the incline as a high-school subject while botany, as generally taught, is unpopular and on the decline.

The mastery (?) of some two or three hundred abstract principles and laws, together with the solving of several hundred mathematical problems and the performing of fifty or more generally nonsignificant laboratory exercises is usually recognized as the sum total of an adequate high-school course in physics. Such a course has been the bane of life and the Waterloo of thousands, if not millions, of perfectly normal high-school girls. Their frantic efforts to surmount this obstacle to their goal—graduation—is pathetic. But who will say that the average girl cannot be interested in, and led to appreciate and to understand, the essential principles of that most difficult portion of physics, mechanics, when we see her sitting confidently at the steering wheel of the family car, safely guiding it through the crowded thoroughfare of the city? The fact is that she is easily capable of intense interest in gears, in revolutions per

minute, and in differentials, as well as in proper mixtures, induction coils, magnetos, spark plugs, and storage batteries, provided these be taught, not as abstractions, but as vital parts of the car she drives.

But the question arises, Just how is this reorganization of science upon the principle of developing the essential laws and principles out of a study of applied science to be effected? Or again, Is it possible to organize science materials, while following such a plan, into logical units of instruction having educational value?

Time and experience alone can fully answer the first of these questions. At the present time, however, a partial answer, an answer so far as the first course in science is concerned, is being worked out. Some of the one-year courses in general science now available is the tentative answer. Natural science, *organized knowledge concerning nature*, is not a static thing; it is ever changing; it is ever expanding and presenting new insights and new problems concerning human welfare. Likewise, no course in general science can long remain static; it must be modified and adapted to the ever changing content of our knowledge concerning the natural world about us. Nevertheless, certain fundamental principles of organization would seem to be permanent and abiding. It is the purpose of this paper to point out some of those permanent fundamental principles.

## SCHEMATIC OR GRAPHIC ILLUSTRATION OF THE ORGANIZATION OF SCIENCE COURSES

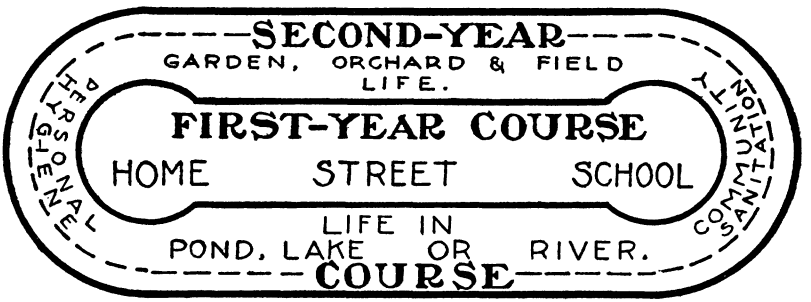
Unsatisfactory and incomplete as it must necessarily be, schematic or graphic illustration of courses of study is frequently of value because it gives at a glance the essential features of the organization. A common organization of science courses, as they have been arranged in the past, is shown by the following:

| 1st Year | 2d Year | 3d Year | 4th Year |
|---|---|---|---|
| Physical Geography; Physiology | Zoölogy; Botany | Chemistry; Physics | Physics; Chemistry |

The Biology Committee of the National Educational Association presented the following scheme at the meeting in July, 1916:

| General Course Required | | | | Elective Courses | |
|---|---|---|---|---|---|
| 1st Year | | 2d Year | | 3d Year | 4th Year |
| Physical Science | Plant Life | Animal Life | Man | The Special Sciences | |

Such an organization as is presented in either of these schemes has aptly been styled a "vertical stratification of science." In contrast to any similar organization of science courses we suggest the following as indicating the field or scope of general science courses covering the first two years:




Such an organization of science presumes that the science materials for the first year's course shall be selected chiefly from the applications of science as found in the home, in the school and along the street leading from the home to the school. Naturally physical science materials, such as lighting and heating systems, refrigeration, water supply and sewage disposal, the use of labor-saving machines, together with the weather, climate, food and nutrition, micro-organisms, and similar materials will chiefly comprise the course and personal and community welfare will be the crucial point of attack. The second year's course will reach out on every side for materials and will include plant and animal life as found in the garden, the orchard and the field, in the pond, river, or lake. It will also include a more complete study of personal hygiene and

community sanitation. The second year's work will, therefore, deal chiefly with biological materials although the influence of physical environment will everywhere be an important consideration.

Science materials as commonly organized in the special sciences may properly be said to be organized into man-made units while the materials in general science may properly be said to be organized into Creator-made units. Nature presents no fundamental relationships, no functioning activities, which necessitate the study and comparison of all the forms and variations of roots, then of stems, then of leaves, and finally of fruits before a student may proceed to study and acquire an understanding of the essential characteristics of the corn plant and of the conditions best suited to its growth and maturity. Nature presents as a logical unit of study the *relation between* the root of the corn, the stem of the corn, the leaf of the corn, and the fruit of the corn. The entire corn plant together with its relation to the soil, to moisture, to climate, and to the animal life which affects its growth is the natural, Creator-made unit. A study of corn, then of wheat, then of clover, then of the potato, then of the beet, then of the onion, and so on, until the plant life of the student's environment is fairly covered enables the student to grasp all of the essential principles taught in special science and at the same time approaches the various problems along the line of his natural interests.

Similarly, there is no intrinsic value to the girl in the study of all forms of gears, and all the various systems employed in the transmission of mechanical power before she is permitted to study a concrete case. The girl who drives a car is certain to be interested in the transmission system of her own car and she delights in obtaining such a knowledge of it as will enable her more completely to control her car as a result. But the real unit of study which appeals to her as logical and natural includes the essential mechanical features of the car; it includes, not only the transmission system, but it includes as well the source of power and the controlling devices; it includes proper mixtures, proper timing of ignition, spark plugs, magnetos, and storage batteries as well. Moreover, she must see all of these in their proper relation to each other.

Such an organization is the Creator-made unit, the unit of applied science. Such an organization presents the unit which has significance and therefore is of interest to her. Such an organization may properly be called a "horizontal stratification of science" in contrast to the "vertical stratification of science" as presented by special science.

There is positively no difficulty in organizing the science materials involved in such courses into suitable, logical units of instruction of as great, if not greater, theoretical educational value than are the usual units of special science. In addition, experience shows the writer that such an organization of science materials secures and holds the interest of the student, with the result that a permanent, abiding interest in science is developed and a permanent scientific attitude of mind results.

It is as yet a question whether the recommendation of the Biology Committee, that the last two years of the high-school course shall be devoted to the study of elective special science, is the best possible solution. It is doubtless true that with greater maturity and with fuller knowledge of the significance of science there comes a time in the life of each of us when we do develop an interest in the abstract, philosophical aspects of science. Whether that stage is usually reached by the student when he enters upon his Junior year of high-school work is a question. Many students of education doubt it. In any case it would certainly seem wise that in most high schools specific courses in agriculture, domestic economy, and household science should find a place in the last two years of high-school course.

## THE SPECIAL SCIENTIST'S CONTENTION

The contention is made by some of the advocates of special science that the reorganization of high-school science along the lines here proposed means the reversing of the wheels of progress in all science teaching. The special science teachers in colleges and universities have been bold in declaring that the work done in the high school has to be done over again in the college classes; they say that there is really little difference in the progress made by those who have had the high-school work and those who have not.

But some of the advocates of special science insist that we are just now at the turning-point; they say that we are just now realizing our mistakes, that we have just discovered how to adapt the subject-matter and methods of instruction so as to secure and hold the interest of the students and to teach science courses successfully. In short, they say that we have just learned that special science courses must be humanized. Moreover, they point out the fact that all college and university instruction prepares the young high-school teacher to teach special science. "If these teachers have not made a success of teaching special science in the high school," to quote one of their most distinguished leaders, "the mess they would make of it were they to attempt to teach general science must be left to the imagination." In general, they say that to abandon the teaching of special science, in a part or all of the high-school course, and adopt the general science organization would mean the forfeiture of the progress made, and a loss of the benefit of the experience gained, during some two or three generations of science training and science teaching and to turn a well-ordered, logical system of instruction into confusion and chaos.

## THE ANSWER

These champions of special science have not yet proved, nor do we believe that they can prove, that any of the special sciences as now taught in the high school are gaining materially in interest, popularity, or effectiveness. Nothing is more evident than that physical geography and physiology, commonly first-year science courses, never before suffered so great a decline as during the past five years. First-year general science has already largely displaced them. Botany and zoölogy are, in many sections of the country, giving place to agriculture. The records of higher institutions requiring elementary physics and chemistry for entrance to certain courses show an ever increasing percentage of applicants knocking at their doors without these prerequisites. If special science courses are really gaining in popularity, interest, or effectiveness, available records do not reveal the fact nor does the testimony of students, science teachers, and administrative officers reveal it.

Again, however true the contention may be that college and university courses in science prepare the young teacher for teaching special science only, this fact does not justify the retention of such courses in the early years of the high school, if our contention that such courses are unsuited to the interests and needs of beginning high-school students is valid. If special science is not in harmony with the foundation principles which underlie successful science teaching in the early years of the high school, the remedy lies only in a readjustment of the science courses in such colleges and universities as aspire to prepare high-school science teachers. The public high school exists for the benefit of the children of the common people; it must be so organized as best to serve the interests and welfare of the millions of young people who must complete their education within its doors. If the usual courses in special science now offered by the higher institutions do not prepare the teacher to teach general science, colleges, universities, normal schools, and teachers' colleges have no alternative but so to adjust their courses that their graduates *can* properly handle the courses required by the high school.

It is not certain, however, that teachers fairly well prepared to teach the special sciences cannot also teach courses in general science with fair success. In all the smaller high schools, the country over, science teachers are now teaching, not a single science, but often all the sciences and frequently other branches, such as mathematics, literature, or history. It is common practice to require the science teacher in such schools to take charge of the work in agriculture or domestic science. Furthermore, during recent years, courses in general science have been taught in many schools by these same teachers trained only in special science. That such courses in general science are being continued year after year and are, in general, being pronounced a success would seem to be a sufficient contradiction to the statement that our present corps of science teachers are not fairly well equipped to teach general science.

## SUMMARY

It is our contention that special science in the high school has been a disappointment, not chiefly on account of poorly prepared

teachers but chiefly because the selection and organization of subject-matter and the methods of approach and development have been fundamentally unpedagogical. The natural interest of the student just beginning the study of science lies in the applied phases of science as it affects his own personal welfare and the welfare of the community in which he lives. The fourteen-year-old boy or girl is not a philosopher; abstract generalizations and principles of science, that is, special science as usually taught, so-called "pure science," is foreign to his interests and his ways of thinking and is therefore distasteful to him. Only the genius, the teacher of unusual personality and ability, who is inspired by his own devotion to the subject, can interest a class of beginners in that phase of science. The ordinary teacher, on the other hand, who is fairly well prepared in the academic phases of science can succeed fairly well with the beginning class if the materials are organized as general science and the materials selected deal with the applied phases of science as found in the environment of the student, because he then has the natural interest of the student to aid him.